Linear Pulsation Properties of the Proto-Planetary-Nebula Stars(Proceedings of the Workshop on the Hydrodynamic Study of Accretion Disks and Pulsating Stars)

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Linear Pulsation Properties of the Proto-Planetary-Nebula Stars

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1. There may exist stars during and just after the asymptotic giant branch (AGB). V441 (89) Herculis is a candidate star. Because the star have been observed for long time, it is reasonable to compare the observed changes of the color and the period with theoretical values. Fernie and Sasselov (1989) have discussed the evolutionary changes of the pulsation periods based on those of the effective temperature, to compare those with observational data. They used Worrell's theoretical results (Worrell 1986) and have found that the observational changes of the period and the color are too small compared with the theoretical values. The changes of theoretical results consist of two materials : one is the speed of the star on the HR diagram by stellar evolution, and the other is the pulsation properties of the stars. The main aim of present note is to examine the effect of opacities on the pulsation periods. We calculated the pulsation periods based on new opacities (Iglesias and Rogers 1991), and compare them with the data reported previously.

2. The code we used here are constructed in the Astronomical Institute of Tôhoku University. It is essentially a Castor code (Castor 1971). We ignored convection since the gradient of stellar envelope is nearly equal to the purely radiative one for these stars. To calculate the atmospheres the effect of sphericity on the total flux is taken into account. The radiative transfer is formulated by using the gray approximation. The OPAL opacities are used with the chemical composition of population II, (Y, Z) = (0.299, 0.001). For obtaining the linear nonadiabatic (LNA) periods, we used Zalewski's procedure that the effect of nonadiabaticity changes from zero to unity step to step. This help us to select the ordinary modes with the strange modes. The construction of model atmospheres is not so easy for luminous less massive stars. The calculation should be done carefully. Fortunately, we have succeeded in constructing models covering V441 Her.

3. To compare the results with those of Fernie and Sasselov (1989), we choose the effective temperature of 5888 K ($\log T_{\rm eff} = 3.77$) for the models. We denote the period as Π, and the radius, R. Π, is fixed as 65 days (Fernie 1991). The gradient of $\log R$-$\log \Pi$ relation is less steep for pulsationally unstable models. We used the exponents $(R/\Pi)(\mathrm{d}\Pi/\mathrm{d}R) \sim$ 1.1, 0.6, and 0.9, for the masses of 0.644, 0.6, and 0.565 solar masses, respectively. Results are very similar to those of Worrell which is found in Fernie and Sasselov (1989). The changes of opacities affect the pulsation periods a little.

4. The pulsation periods yellow bright stars are calculated by using new radiative opacities. Schönberner (1992) suggests that the speed of evolution, $\mathrm{d}T_{\mathrm{eff}}/\mathrm{d}t$, becomes slow when we take mass-loss into account. The combination of his results of stellar evolution and our pulsation properties will yield new criterion to check the stellar evolution theory by using observational data on the variable stars.

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